Clin Orthop Relat Res (2010) 468:1506–1513
DOI 10.1007/s11999-009-1169-z

SYMPOSIUM: CURRENT CONCEPTS IN ROTATOR CUFF DISEASE AND TREATMENT

Isokinetic Muscle Performance Test Can Predict the Status of Rotator Cuff Muscle

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Published online: 21 November 2009

Abstract

Background The isokinetic muscle performance test (IMPT) is a validated and objective method used to evaluate muscle function but it is unknown whether it correlates with severity of rotator cuff tears.

Questions/purposes We asked whether peak torque and total work deficit on the IMPT correlated with the preoperative manual muscle test (MMT), tear size, fatty degeneration (FD) of cuff, and postoperative cuff integrity in patients after rotator cuff surgery.

Methods We evaluated 221 patients who had undergone rotator cuff repair; of these 86 had the IMPT and a CT arthrogram (CTA) 1 year after surgery.

Results We found a correlation (r = 0.125 ~ 0.464) between the preoperative IMPT and MMT. The IMPT deficit was greater in rotator cuff muscles with larger tears and greater degree of FD. Preoperative external and internal rotation deficits on the IMPT were related to the risk of cuff detachment on the postoperative CTA (r = 0.290, 0.319), and the postoperative abduction deficit was greater than 40% of the contralateral side indicating cuff detachment.

Conclusions The IMPT provides objective and quantitative data for estimating the preoperative status of rotator cuff tear and can provide baseline data for postoperative anatomic assessment in patients with rotator cuff disorders.

Level of Evidence Level II, prognostic study. See the Guidelines for Authors for a complete description of levels of evidence.

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Each author certifies that his or her institution has approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.
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Introduction

The manual muscle test (MMT) is widely used to clinically evaluate muscle strength. Its frequent use is attributable mostly to the ease with which the technique is performed in a short time with no instrumentation cost [11]. However, this technique has been criticized for its subjectivity and lack of reliability in the good to normal ranges [1, 20, 23]. Therefore, the isokinetic muscle performance test (IMPT) of the shoulder has been advocated because muscle strength can be objectively measured [8, 9, 19, 24]. The IMPT reportedly has high accuracy and test-retest reliability in evaluating the shoulder musculature complex [17, 18], and provides information regarding patients' actual muscle function and strength [2]. One study suggested the decreased strength of the shoulder found with the IMPT preoperatively recovered after successful reconstruction

[19]; however, whether and how the IMPT relates to functional (MMT) and anatomic factors (tear size, FD of the cuff and postoperative cuff integrity) is unclear. We presumed IMPT would provide more specific definitions of shoulder strength, as measured by peak torque and total work in patients with rotator cuff tears.

We therefore asked whether IMPT would correlate with the preoperative (1) MMT; (2) tear size; and (3) severity of FD; and if postoperative cuff integrity could be predicted based on the difference of preoperative and postoperative IMPT results.

Patients and Methods

We retrospectively reviewed all 317 patients with unilateral full-thickness and partial-thickness rotator cuff tears without shoulder stiffness who had the IMPT and arthroscopic rotator cuff repair between February 2004 and April 2007. We excluded 96 patients who had: (1) any procedures to the shoulder other than those being investigated; (2) a symptomatic lesion in the contralateral nonoperated shoulder; (3) any inflammatory lesion of either shoulder that could affect function; and (4) severe painful stiffness or pseudoparalysis that caused them not to initiate and endure loading against a 60°/second load, resulting in data not being obtained for IMPT. This left 221 patients: 104 men and 117 women with an average age of 59.7 years (range, 34–78 years; standard deviation, 8.5) (Table 1). Full-thickness tears in 208 of the 221 patients and partial-thickness tears in the remaining 13 were determined arthroscopically at surgery. Preoperative FD was evaluated by MRI owing to its reported more conclusive capacity [5], but CTA was performed for postoperative cuff integrity for cost-effectiveness, less time, and because it shows no foreign material artifact. All the study protocols were approved by the Institutional Review Board of the first author's institution, and all patients in the study gave written informed consent.

The IMPT was performed up to 1 week before the surgery using a Biodex System 3 PRO® (Biodex Corp, Shirley, NY). The test was performed with the subject in a sitting position with two bands strapped across the chest; a footrest was not used (Fig. 1). Abduction was tested with the patient's trunk supported in a reclined position 40° from the vertical in the scapular plane between 0° and 110°

Fig. 1 The method to perform an isokinetic muscle performance test (IMPT) is shown.

Table 1. Demographic data and clinical variables

Variables	Data
Gender	M:F = 104:117 (47.1%:52.9%)
Age	59.74 ± 8.5*
Rotator cuff tear	Full-thickness tear: 208 Partial-thickness tear: 13
Combined pathology	SLAP lesion Type I: 2 SLAP lesion Type II: 7
Size of the tear†	Small: 42, medium: 113, large to massive: 66
Preoperative FD of SSP (grade)	Grade 0: 13, Grade 1:28, Grade 2: 85, Grade 3:54, Grade 4: 41
Preoperative FD of ISP (grade)	Grade 0: 41, Grade 1:111, Grade 2: 44, Grade 3: 14, Grade 4: 11
Preoperative FD of SSC (grade)	Grade 0: 70, Grade 1: 110, Grade 2: 24, Grade 3: 6, Grade 4: 11
Postoperative cuff integrity‡ (n = 86)	Grade I : 38 Grade II : 21 Grade III : 27

* Data represents the mean ± SD; †small tear (≤ 1 cm), medium (1-3 cm), large to massive (> 3 cm); ‡Grade I: anatomic healing with no contrast media leakage, Grade II: maintenance of insertion to the footprint with contrast media leakage, Grade III: detachment of reattached cuff with contrast media leakage; FD = fatty degeneration; SSP = supraspinatus; ISP = infraspinatus; SSC = subscapularis; M = male; F = female.

abduction, and external rotation and internal rotation were tested with the shoulder in a neutral position and the elbow flexed to 90° [3, 8]. We measured the isokinetic strength (peak torque [PT] and total work [TW]) deficit in abduction, external rotation, and internal rotation at a 60°/second load. Assuming the contralateral side was normal, we then computed a percentage of these values compared with the contralateral shoulder for each subject. For PT (Nm), we used the highest torque value during five repetitive isokinetic efforts. TW (J) indicated the work performed by the subject in the repetition that produced the greatest value during five repetitive isokinetic efforts [8, 19].

The MMT was performed by the first author (JHO) and by one of the two coauthors (JPY, JYK) separately on the day before the surgery using a six-grade scale from the Modified Medical Research Council Scale [4]. A consensus opinion was obtained when there was disagreement, although the MMT reportedly has high interobserver reliability [4, 20]. Measurements were made for the supraspinatus (SSP), infraspinatus (ISP), and subscapularis (SSC) by abduction, external rotation, and internal rotation, respectively. To compare results of the measurements, the MMT was performed in standardized positions. Internal rotation and external rotation were tested with the subject's shoulder in 0° abduction, neutral rotation, and 90° elbow flexion. An assistant stabilized the patient's elbow against the patient's waist to help maintain a stable position during the test. The abduction in the plane of the scapula was tested at 60° from the coronal plane, as described by Pearl et al. [16].

The size of any full-thickness rotator cuff tears was measured with a probe (with 5-mm markings, [AR-10010]; Arthrex, Naples, FL) during the course of arthroscopic surgery by the first author (JHO). After débridement of the torn end, the AP dimension was measured at the lateral edge of torn cuff and medial retraction was measured as the distance from the apex of the tear to cuff insertion of the humeral head [21] (Fig. 2). The larger value of the two measurements (AP dimension and medial retraction) was used as tear size; the tears were divided into three groups based on size: small (less than 1 cm), medium (1–3 cm), and large to massive (greater than 3 cm).

All surgical procedures were performed by one surgeon (JHO). Arthroscopic subacromial decompression, including acromioplasty, was performed in all patients. Combined SLAP lesions (two Type I lesions; seven Type II lesions) (Table 1) were débrided but not fixed to the superior glenoid tubercle in all patients. Débridement was performed in the patients who had a partial tear less than 50%, and tenotomy or tenodesis was performed in patients with tears larger than 50%. The numbers of anchors used were based on the size of the tear; usually one or two anchors were used for a small tear, three or four anchors were used for a medium tear, and four or more anchors were used for a large to massive tear. A bioabsorbable (Bio-Corkscrew; Arthrex, Naples, FL) or metal anchor (TwinFix; Smith & Nephew Endoscopy, Andover, MA) was used.

Immobilization was maintained with the abduction brace. The duration of immobilization was based on the tear size measured at the time of the surgery: 4 weeks for small tears, 5 weeks for medium tears, and 6 weeks for large to massive tears. Muscle strengthening exercises were started 9 to 12 weeks postoperatively. All sports activities were permitted after 6 months postoperative. Rehabilitation was referred to and supervised by the Department of Rehabilitation in our institution.

The preoperative FD of the rotator cuff muscles was evaluated and recorded by one musculoskeletal radiologist (JAC) using MRI. We used the grading system developed by Goutallier et al. [6], on the same level of the cut that showed the coracoid base where the spine and body of the scapula form a Y shape.

For analysis between the IMPT and postoperative cuff integrity, we recruited 86 patients with postoperative IMPT and CTA simultaneously 12 months or more after surgery. Among the 221 patients, 55 did not have either the postoperative CTA or IMPT, and another 80 had postoperative

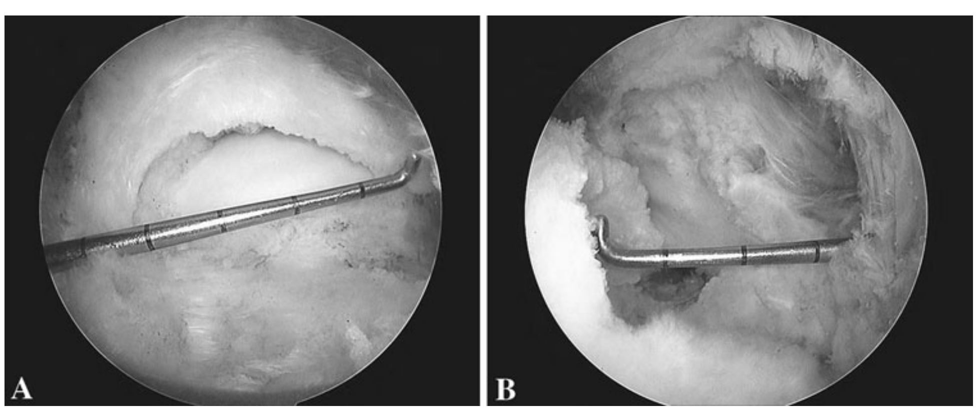

Fig. 2A–B Arthroscopic images show (**A**) the AP dimension and (**B**) medial retraction for measurement of tear size.

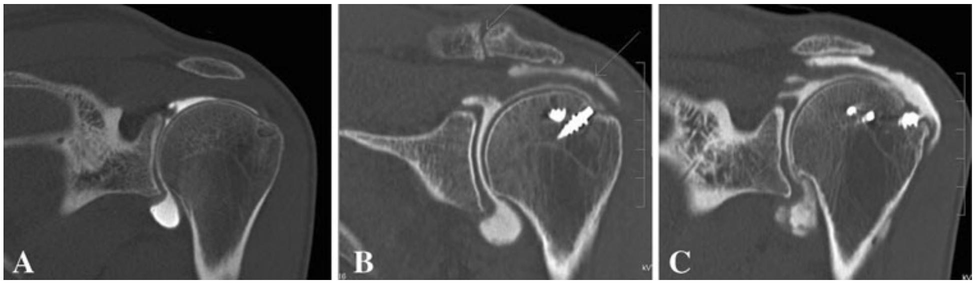

Fig. 3A–C CTAs show the stage of postoperative cuff integrity. (**A**) Grade I is defined as anatomic healing with no contrast media leakage. (**B**) Grade II is defined as maintenance of insertion to the footprint with contrast media leakage. (**C**) Grade III is defined as detachment of a reattached cuff with contrast media leakage.

CTA and IMPT less than 12 months after surgery. Demographic features of the postoperative IMPT group (n = 86) and drop-out group (n = 135) were similar: gender (p = 0.495), age (p = 0.476), tear size (p = 0.377), and FD (p = 0.42–0.921). The mean duration between surgery and the postoperative CTA and IMPT was 15.2 months (range, 12–38.4 months).

The postoperative cuff integrity was evaluated by the same radiologist (JAC) using CTA. Based on a previous study [14], we divided integrity into three grades (Fig. 3): Grade I (anatomic healing with no contrast media leakage); Grade II (maintenance of insertion to the footprint with contrast media leakage); and Grade III (detachment of the reattached cuff with contrast media leakage). All MR and CTA images were evaluated again for FD and postoperative cuff integrity by an orthopaedic surgeon (JPY), for analysis of interobserver reliability. Intraclass correlation coefficients (ICC) for FD showed similar results of reliability (SSP = 0.75, 95% confidence interval [CI] = 0.66–0.81; ISP = 0.73, 95% CI = 0.66–0.78; SSC = 0.65, 95% CI = 0.56–0.72) compared with results in a previous study [13]. The ICC for postoperative cuff integrity was excellent (0.82, 95% CI = 0.75–0.89).

We performed correlation and comparative analyses to determine the relationships between the isokinetic strength deficit and the clinical variables. For the correlation analyses, we calculated the correlation coefficients of three categorical variables (MMT, tear size, FD) using Spearman's correlation coefficients. We determined differences in the strength deficits between each subgroup of two categorical variables (tear size, FD) using one-way ANOVA and Scheffe's multiple comparison tests for post hoc analysis. We also performed correlation and comparative analyses to determine whether the isokinetic strength deficit in abduction, external rotation, and internal rotation could predict postoperative cuff integrity. Finally, we determined the 95% confidence interval of the parameter that correlated best with postoperative cuff integrity. All statistical analyses were performed using the SPSS software package (Version 12.0; SPSS Inc, Chicago, IL).

Results

The preoperative IMPT correlated with (r = 0.125–0.464) the preoperative MMT. For the PT and TW deficit in abduction (for SSP), the Spearman correlation coefficients for the MMT and IMPT were 0.252 and 0.340, respectively. For external rotation (for ISP), the coefficients were 0.457 and 0.464. For internal rotation (for SSC), the coefficients were 0.125 and 0.151, respectively (Fig. 4).

The preoperative deficit of the IMPT correlated with (r = 0.272–0.408) tear size (Table 2). The TW deficit had a higher correlation with tear size than the PT deficit, especially for abduction (r = 0.272, 0.370) and external rotation (r = 0.380, 0.408). The preoperative abduction TW deficit was greater ($p < 0.001$) in the larger tear groups. The preoperative abduction TW deficit in the large to massive tear group was greater than the deficit in the other groups. The mean values of preoperative abduction TW deficits were greater in the large to massive tear group than the medium tear group (81.8%: 65.5%, p = 0.016) and the small tear group (81.8%: 48.2%, $p < 0.001$) (Fig. 5).

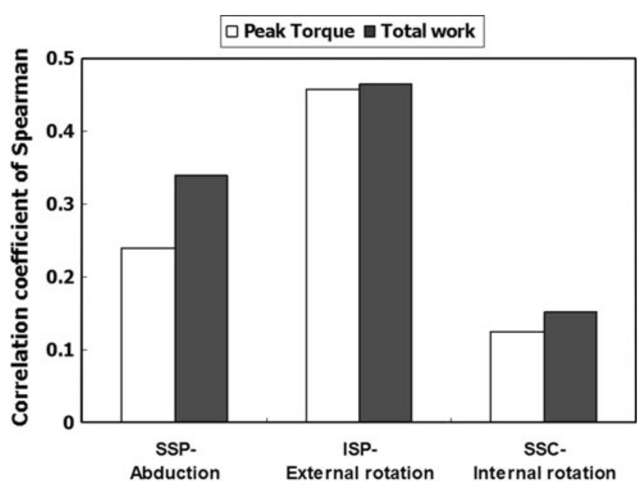

Fig. 4 The graph shows the relationship between the strength deficit in the IMPT and the MMT. A relatively low correlation was found between the IMPT and the MMT. SSP = supraspinatus; ISP = infraspinatus; SSC = subscapularis.

Table 2. Relationship between tear size subgroup and preoperative IMPT deficit

Item of IMPT	CC with tear size	p Value
Abduction peak torque	0.272†	< 0.001
Abduction total work	0.370†	< 0.001
External rotation peak torque	0.380†	< 0.001
External rotation total work	0.408†	< 0.001
Internal rotation peak torque	0.321†	< 0.001
Internal rotation total work	0.353†	< 0.001

†p < 0.01;IMPT = isokinetic muscle performance test; CC = correlation coefficient of Spearman.

The preoperative deficits for abduction, external rotation, and internal rotation correlated with (r = 0.238–0.436) FD of SSP, ISP, and SSC (Table 3). The preoperative abduction TW deficit was greater ($p < 0.001$) in patients with a higher FD grade of SSP. The preoperative abduction TW deficit in Grade 0 FD of SSP was less than in the other FD grades (mean value, 15.4% for Grade 0, 62.2% for Grade I, 64.0% for Grade II, 68.9% for Grade III, 90.3% for Grade IV; p = 0.001, < 0.001, < 0.001, < 0.001, respectively) (Fig. 6). However, we observed no differences between the adjacent

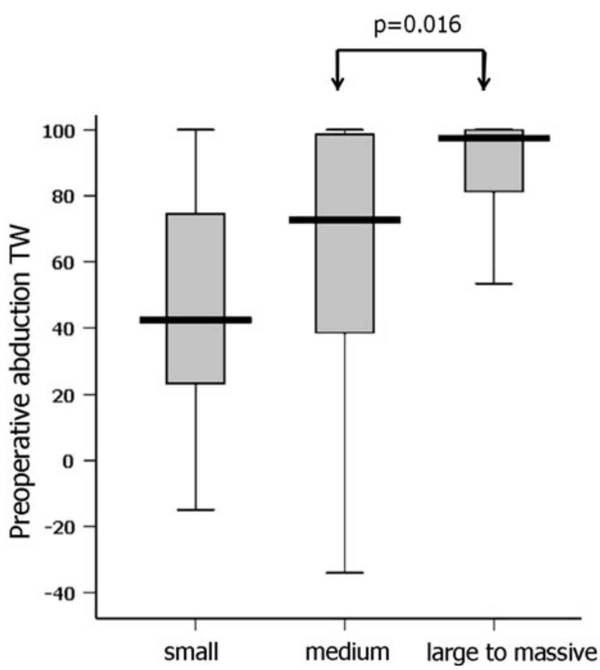

Fig. 5 A box plot shows the relationship between the preoperative abduction TW deficit and tear size. The preoperative abduction TW deficit in the large to massive tear group was greater than in the other groups.

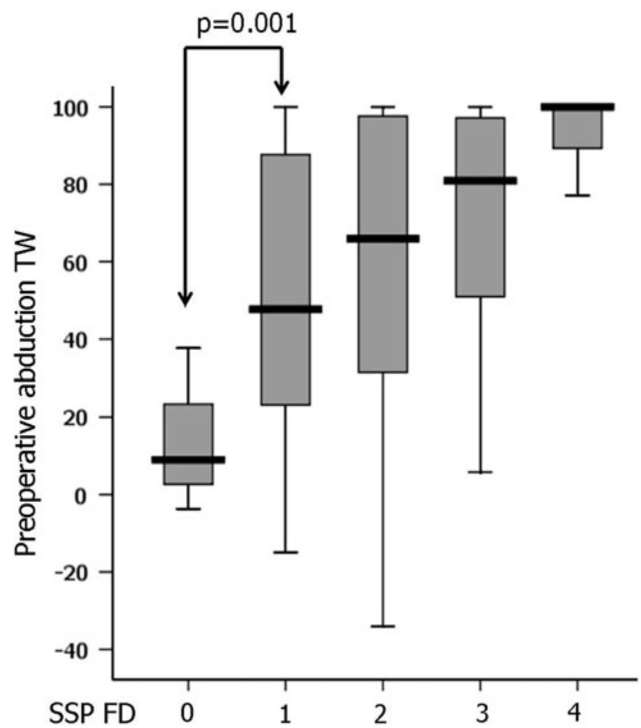

Fig. 6 A box plot shows the relationship between the preoperative abduction TW deficit and the FD of the SSP. The preoperative abduction TW deficit in Grade 0 FD of the SSP was less than the other FD grades.

Table 3. Relationship between preoperative FD of the rotator cuff muscles and preoperative IMPT deficit

Item of IMPT	FD of SSP		FD of ISP		FD of SSC	
	CC	p Value	CC	p Value	CC	p Value
Abduction peak torque	0.365†	< 0.001	0.320†	< 0.001	0.323†	< 0.001
Abduction total work	0.432†	< 0.001	0.365†	< 0.001	0.389†	< 0.001
External rotation peak torque	0.429†	< 0.001	0.390†	< 0.001	0.271†	< 0.001
External rotation total work	0.436†	< 0.001	0.401†	< 0.001	0.280†	< 0.001
Internal rotation peak torque	0.264†	< 0.001	0.311†	< 0.001	0.238*	0.001
Internal rotation total work	0.363†	< 0.001	0.385†	< 0.001	0.268†	< 0.001

* p < 0.05, †p < 0.01; IMPT = isokinetic muscle performance test; FD = fatty degeneration; CC = correlation coefficient of Spearman; SSP = supraspinatus; ISP = infraspinatus; SSC = subscapularis.

Table 4. Relationship between postoperative cuff integrity on followup CTA and IMPT deficit

Item of IMPT	CC	p Value
Preoperative		
Abduction peak torque	0.087	0.456
Abduction total work	0.105	0.366
External rotation peak torque	0.294†	0.009
External rotation total work	0.290*	0.010
Internal rotation peak torque	0.265*	0.016
Internal rotation total work	0.319†	0.003
Postoperative		
Abduction peak torque	0.220	0.081
Abduction total work	0.503†	< 0.001
External rotation peak torque	0.169	0.185
External rotation total work	0.334†	0.009
Internal rotation peak torque	0.179	0.157
Internal rotation total work	0.191	0.130

* $p < 0.05$, †$p < 0.01$; CTA = computed tomographic arthrogram; IMPT = isokinetic muscle performance test; CC = correlation coefficient of Spearman.

Table 5. Postoperative abduction total work deficit based on postoperative cuff integrity

Postoperative cuff integrity	Abduction total work deficit	
	Mean	95% confidence interval
Grade I (n = 38)†	10.061	−0.25–20.37
Grade II (n = 21)	19.935	2.38–37.48
Grade III (n = 27)	54.999*	38.98–71.00*

* Grade III was significantly different (p = 0.006) by post hoc analysis; †Grade I: anatomic healing with no contrast media leakage, Grade II: maintenance of insertion to the footprint with contrast media leakage, Grade III: detachment of reattached cuff with contrast media leakage.

subgroups of ISP and external rotation and SSC and internal rotation.

The preoperative and postoperative deficits of IMPT correlated with postoperative cuff integrity (r = 0.087–0.503) (Table 4) with postoperative abduction TW deficit showing the best correlation (r = 0.503) with postoperative cuff integrity. Lesser correlations were observed between the preoperative PT and TW deficits in external (r = 0.294, 0.290) and internal rotation (r = 0.265, 0.319) and the postoperative TW deficit in external rotation (r = 0.334). Postoperative abduction TW deficit was increased ($p < 0.001$) when rotator cuff detachment occurred. The mean postoperative abduction TW deficit of the detachment (Grade III) group was greater (p = 0.006) than the Grade II group (54.9% versus 19.9%, respectively) (Table 5; Fig. 7). The 95% confidence intervals of the mean value of the detachment groups were 38.98% to 71.00%.

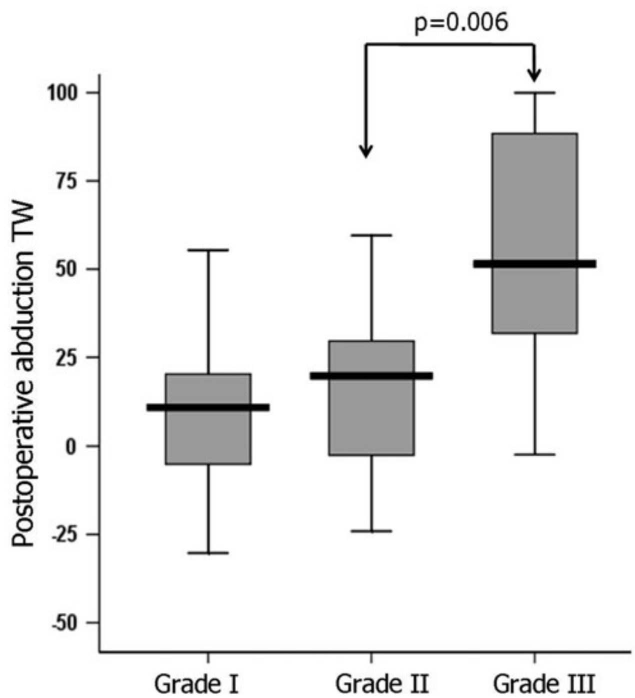

Fig. 7 A box plot shows the relationship between the postoperative abduction TW deficit and the postoperative cuff integrity. The postoperative abduction TW deficit in the detachment group was greater than in the other groups.

Discussion

The IMPT of the shoulder is being used more frequently in clinical practice. However, there is relatively little published information regarding the correlations between IMPT with the clinical variables. Because of this lack of information, valuable data obtained from IMPT have not been interpreted sufficiently for clinical purposes. Therefore, we designed our study to determine whether the IMPT reflected the preoperative clinical factors (MMT, tear size, FD), and whether postoperative cuff integrity can be predicted based on preoperative and postoperative IMPT results.

In interpreting the findings of this study, several limitations should be acknowledged. First, preoperative pain might have interfered with the isokinetic test, potentially underestimating true strength, and the improvements seen at postoperative testing might have resulted, at least in part, from the effects of the acromioplasty. Although it is difficult to identify the degree to which pain affected the isokinetic results or exclude any effect, we excluded patients who were unable to initiate and endure the test because of pain-related pseudoparalysis. Additionally, we performed five repetitions for each isokinetic test to obtain the best value and we performed acromioplasty on all patients. Second, in a previous study the contralateral healthy shoulder was observed to have an asymptomatic cuff tear, particularly in older patients [25]. It could have influenced the strength deficit as measured by IMPT, potentially leading to underestimates. The lack of radiologic screening, such as sonography, of the contralateral shoulder owing to the retrospective study design and cost-effectiveness is a limitation, although patients with symptoms of the contralateral shoulder were specifically excluded by physical examination. Third, postoperative CTA and IMPT were the invasive and expensive procedures for routine clinical purpose, therefore analysis between IMPT and postoperative cuff integrity were performed in 86 patients, not all the patients included in the study. Although the population of the postoperative IMPT group did not differ substantially from the drop-out group regarding gender, age, tear size, and FD, however, there may be some unpredictable selection bias.

We found a low correlation between the IMPT and MMT although the latter was performed by one orthopaedic surgeon. Similarly, in previous studies, only weak correlations between the MMT and IMPT were reported [12, 18]. Numerous factors affect muscle strength including pain and ROM; however, muscle strength as determined by the MMT provides only limited and indistinct information regarding the tear size or FD of the rotator cuff muscle.

Preoperative strength deficits on the IMPT size were closely related to tear size and the much larger tears were associated with lower strength. Rokito et al. [19] used isometric strength assessment and found that in patients with small- to medium-sized tears, the mean abduction strength progressed from 44% of the contralateral side before surgery to 81% at 6 months postoperatively and 112% at 12 months postoperatively, and for patients with large to massive tears, the mean abduction strength progressed from 42% of the contralateral side before surgery to 80% at 6 months postoperatively, and 86% at 12 months postoperatively. We found the correlation between strength and tear size was greater in the TW deficit than in the PT deficit. This suggests pain prevented the subjects from attaining the highest torque output during exercise. TW represents the sum of torque during exercise; therefore, this might reduce the effect of the pain, and it thus might provide more objective and reliable information than PT regarding tear size. The IMPT may have a tendency not to respond to small changes in strength, but to effectively respond to larger changes in rotator cuff function. Our post hoc analysis is consistent with this interpretation. We therefore suggest large-to-massive cuff tears should be suspected with a preoperative TW deficit in abduction on the IMPT.

Preoperative TW deficit in abduction and external rotation related to FD of SSP. As other studies have shown, SSP and ISP contribute almost equally to shoulder abduction, and an SSP deficit decreases the strength of external rotation as much as an ISP deficit does [7, 8, 10, 15]. It is difficult to say from our data that a strength deficit on the IMPT is a direct indicator for the FD; however, the IMPT can provide additional information in addition to tear size.

Data from the IMPT predicted postoperative cuff detachment, and preoperative PT and TW deficits in external and internal rotation were associated with this, particularly a preoperative internal rotation TW deficit. Larger tears that might increase the risk of a postoperative cuff detachment could extend into the SSC and cause more disuse atrophy of the SSC in such tears. However, for postoperative findings, the most correlated parameter was a TW deficit in abduction and a lesser related parameter was in TW deficit external rotation. The apparent importance of postoperative abduction as a predictor of postoperative cuff detachment may be because the external and internal rotation strength is preserved or restored as a result of force coupling in the AP direction by the ISP and SSC, even in the case of cuff detachment after surgical repair. The cuff detachment group was well differentiated from the anatomic healing group, and when the postoperative abduction TW deficit on the IMPT was greater than approximately 40%, postoperative cuff detachment was likely to have occurred. Previous studies showed that rotator cuff atrophy and FD of the SSP and ISP are predictors of postoperative cuff detachment [6, 22]. Consequently, we believe a postoperative abduction deficit may be a useful predictor of cuff detachment. Although the IMPT cannot replace the CTA or MRA, the strength of the cuff muscle determined using IMPT can quantitatively reflect postoperative anatomic status of the repaired cuff.

An IMPT of the shoulder provides objective, reliable, and valuable perioperative data, which can be used to estimate the functional status of the rotator cuff muscles and can provide quantitative data for anatomic assessment of the rotator cuff. Also, these findings can offer objective guidelines for interpreting muscle strength in patients with a rotator cuff disorder.

Acknowledgments We thank Ki Hyun Jo, MD, Hye Ran Kim, and Sang Mi Shim for support with data collection and patient recruitment. We also thank Sung Ju Kim, MPH, for help with the statistical analyses and Jung-Ah Choi, MD, PhD, for radiographic measurements.

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